MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2015/2016

ETM7246 – PASSIVE MICROWAVE CIRCUIT DESIGN

(All sections / Groups)

Xst JUNE 2016
2:30 P.M. – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only .
2. Attempt **ALL FOUR** questions .
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) With an aid of a suitable diagram, describe the FOUR (4) propagation modes in a waveguide or transmission lines.

[8 marks]

(b) Briefly define the following terms related to transmission line theory.

(i) Lossless Transmission Line.
(ii) Characteristic Impedance.
(iii) Voltage Reflection Coefficient.

[6 marks]

(c) A lossless transmission line circuit is shown in Fig. Q1b with characteristic impedance Z_c = 50 ohm, load impedance Z_L = 25 ohm, given that source impedance $Z_s = Z_c$ at 1.8 GHz. Determine the following:

(i) the load reflection coefficient (Γ_L) at 1.8 GHz,

[2 marks]

(ii) the input impedance Z_{in} and the input voltage V_{in}.

[4 marks]

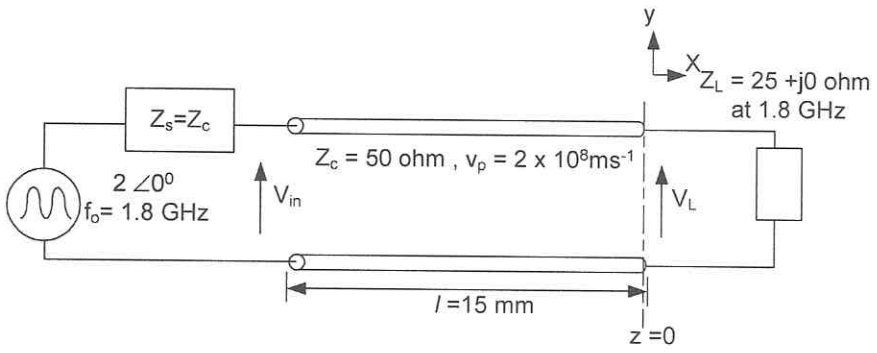

Figure Q1b

Continued . . .

(d) A coaxial line has the following paramters: resistance per unit length, $R' = 6$ ohm/km, inductance per unit length, $L' = 2.2$ mH/km, capacitance per unit length, $C' = 0.005$ μF/km and conductance per unit length, $G' = 0.05$ μmho/km. Determine the following:

(i) the characteristic impedance Z_0 and propagation constant γ at 1 kHz,
[2 marks]

(ii) the attenuation (in dB), phase shift and phase velocity of the signal when the line length is 100 km.

(Note: 1 neper is equivalent to 8.686 dB)
[3 marks]

Question 2

(a) With an aid of a diagram, list out the two examples of circulator usage.
[6 marks]

(b) Compare the characteristics of a T-junction power divider, Wilkinson power divider and resistive power divider. State their advantages and disadvantages.
[6 marks]

(c) Fig. Q2c shows a resistive power splitter. The three terminals of the power splitter are connected to impedance (can be transmission line) of Z_c. Determine the impedance Z_{in} when Port2 and Port3 are terminated with Z_c.
[5 marks]

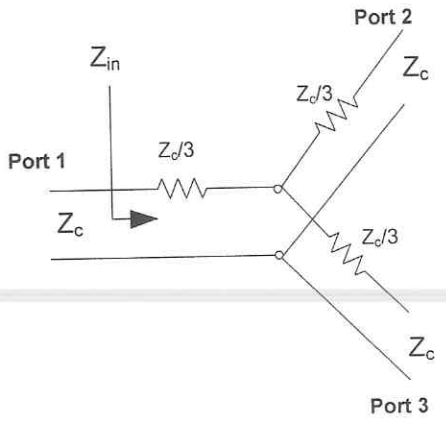

Figure Q2c

Continued . . .

(d) A 2 W power source is connected to the input of a directional coupler with coupling factor, $C = 20$ dB, directivity, $D = 25$ dB and an insertion loss of 0.7 dB. Determine the output powers (in dBm) at the through, coupled, and isolated ports. Assume all ports are matched.

[8 marks]

Question 3

(a) Briefly explain the role of Richard's Transformation in the conversion of lumped filters into distributed filters with the aid of diagrams.

[6 marks]

(b) Using Table Q3, design a 3rd-order Chebyshev band-pass filter with the following specifications: center frequency of 1.8 GHz, 3dB bandwidth of 200 MHz and insertion loss of 0.5 dB. Assumed that the reference impedance is $Z_0 = 50$ ohm. Illustrate the steps from low-pass prototype implementation to the final LC schematic.

[14 marks]

Table Q3 – Chebyshev 0.5 dB ripple LPP table

N	g1	g2	g3	g4	g5	g6	g7
1	0.6986	1.0000					
2	1.4029	0.7071	1.9841				
3	1.5963	1.0967	1.5963	1.0000			
4	1.6703	1.1926	2.3661	0.8419	1.9841		
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000	
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841

(c) With an aid of a diagram, and using Kuroda's identities, illustrate how a short-circuited stub can be converted into a shunt open-circuited stub and vice-versa.

[5 marks]

Continued . . .

Question 4

(a) A quarter-wave matching transformer to match a 40 Ω load to a 75 Ω lossless transmission line is to be designed as shown in Fig. Q4a.

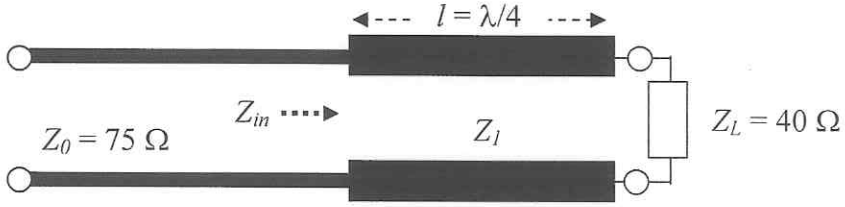

Figure Q4a

(i) Show that the input impedance of the quarter-wave matching transformer,

$$Z_{in} = \frac{Z_1^{\,2}}{Z_L}$$

where Z_1 is the characteristic impedance of the quarter-wave transformer

[5 marks]

(ii) Determine Z_1.

[3 marks]

(b) Design a rectangular microstrip patch antenna on a substrate with dielectric constant (ε_r) 3.20 and thickness (h) 1.5 mm. The antenna must be operating at a centre frequency of 3 GHz.

[8 marks]

(c) Discuss the THREE (3) major types of feeding techniques used in a microstrip patch antenna, and the advantages and disadvantages of each type.

[9 marks]

Continued . . .

Appendix

Design equations for patch antenna

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

for,

$$w/h > 1$$

where h = height of substrate and w = patch width

For an efficient radiator, a practical width that leads to good radiation efficiencies is given as,

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

where

c = speed of light in free space

f_r = resonant frequency

ε_r = dielectric constant of substrate

A approximate relation for the normalized extension of the length is given as,

$$\frac{\Delta L}{h} = 0.412\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)}$$

Effective length of the patch is,

$$L_{eff} = L + 2\Delta L$$

The (actual) physical length is thus,

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L$$

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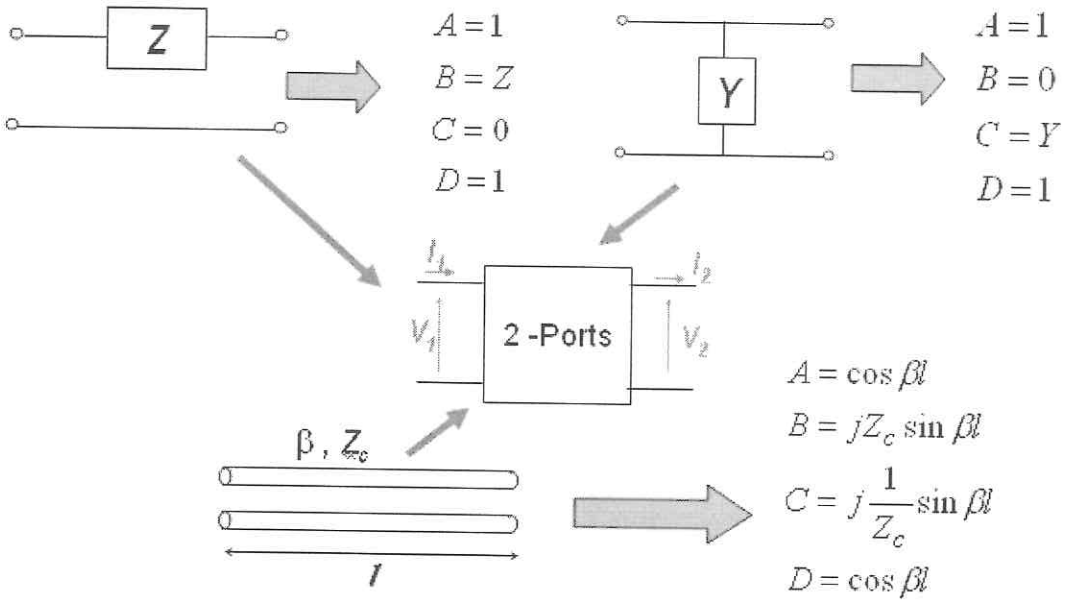
ABCD and S-parameters

ABCD parameters for some simple network



Input impedance and admittance of terminated line:

$$\bar{Z}_{in}(l) = \frac{Z_L + jZ_c \tan(\beta l)}{Z_c + jZ_L \tan(\beta l)} \qquad \bar{Y}_{in}(l) = \frac{Y_L + jY_c \tan(\beta l)}{Y_c + jY_L \tan(\beta l)}$$

Conversion between S and ABCD parameter:

$$A = \frac{(1+S_{11})(1-S_{22}) + S_{12}S_{21}}{2S_{21}} \qquad S_{11} = \frac{A + B/Z_o - CZ_o - D}{A + B/Z_o + CZ_o + D}$$

$$B = Z_o \frac{(1+S_{11})(1+S_{22}) - S_{12}S_{21}}{2S_{21}} \qquad S_{12} = \frac{2(AD - BC)}{A + B/Z_o + CZ_o + D}$$

$$C = \frac{1}{Z_o} \frac{(1-S_{11})(1-S_{22}) - S_{12}S_{21}}{2S_{21}} \qquad S_{21} = \frac{2}{A + B/Z_o + CZ_o + D}$$

$$D = \frac{(1-S_{11})(1+S_{22}) - S_{12}S_{21}}{2S_{21}} \qquad S_{22} = \frac{-A + B/Z_o - CZ_o + D}{A + B/Z_o + CZ_o + D}$$

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